DESIGN CONCEPTS FOR LARGE ANTENNA REFLECTORS

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LARGE SPACE ANTENNA REQUIREMENTS

We are performing a contractual study "Design Concepts for Large Reflector Antenna Structures," which has been underway since June. This is a report on the progress to date. The needs for large antenna structures are illustrated in figure 1, taken from work done by R.V. Powell at JPL. The lines of constant D/λ have been added to emphasize the stringency of some of the future requirements. The conclusion is that apertures from 1,000 to 10,000 wavelengths in diameter will be needed. When this is coupled with the requirement that the surface be true to a small fraction of a wavelength, the conclusion is that surface accuracies of one part in 100,000 will be needed.

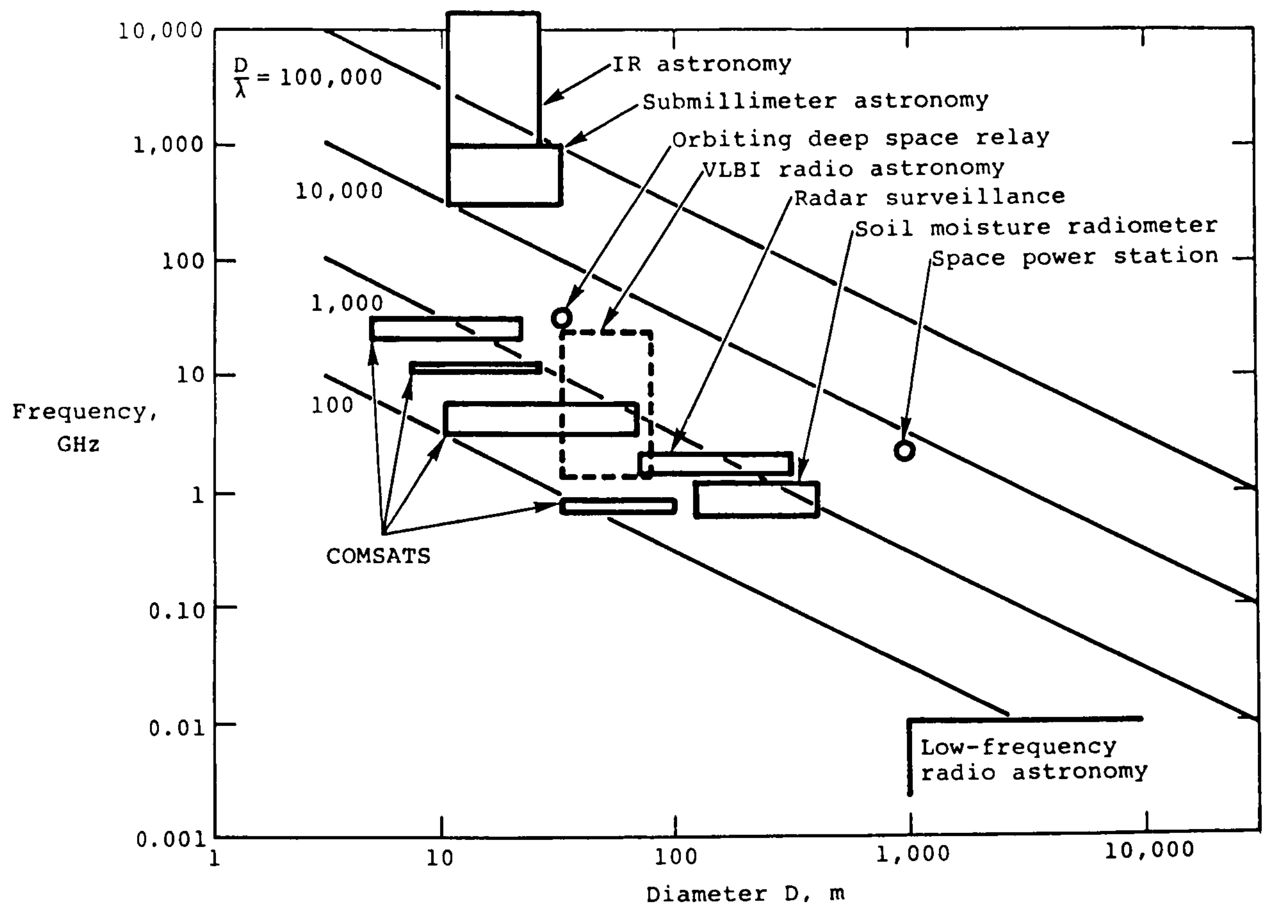

Figure 1

STRUCTURAL CONFIGURATIONS

In this study, we have confined our attention to a type of antenna reflector in which a stiff structure is constructed to hold a membrane-like reflector mesh in the correct position. An important basic restriction in our approach is that the mesh be controlled only by the structure and that no additional local shaping be employed. Furthermore, attention is confined to structures in which no adjustments would be made on assembly. Several possible configurations of this type are shown in figure 2.

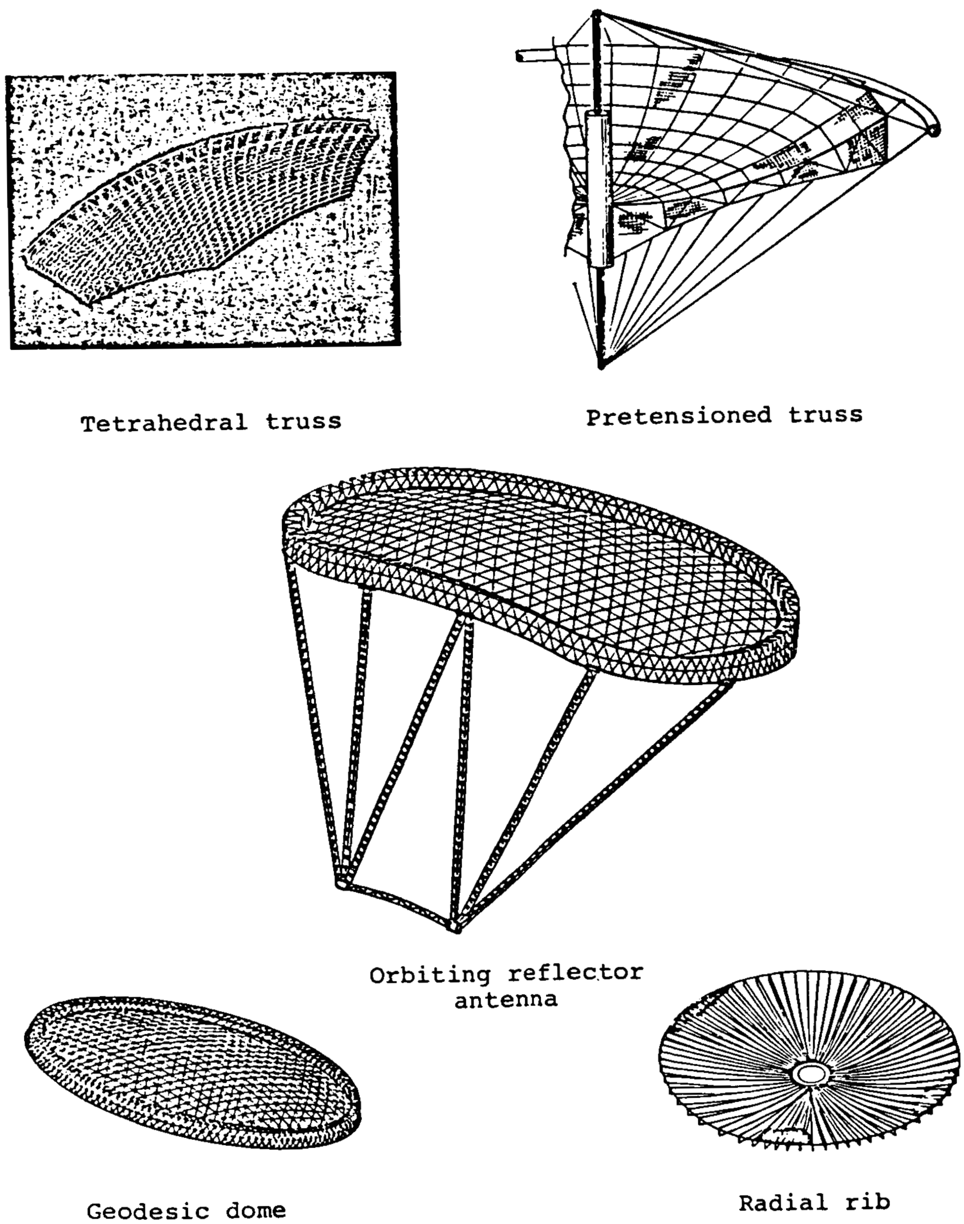

Figure 2

TETRAHEDRAL-TRUSS CONFIGURATION

Primary attention is given to the tetrahedral-truss configuration because of its outstanding stiffness and dimensional stability. It is recognized that this type of construction is relatively complex (see figure 3), especially when the individual facets must be made small enough so that the mesh can be made flat over each facet and still approximate the desired paraboloidal surface satisfactorily.

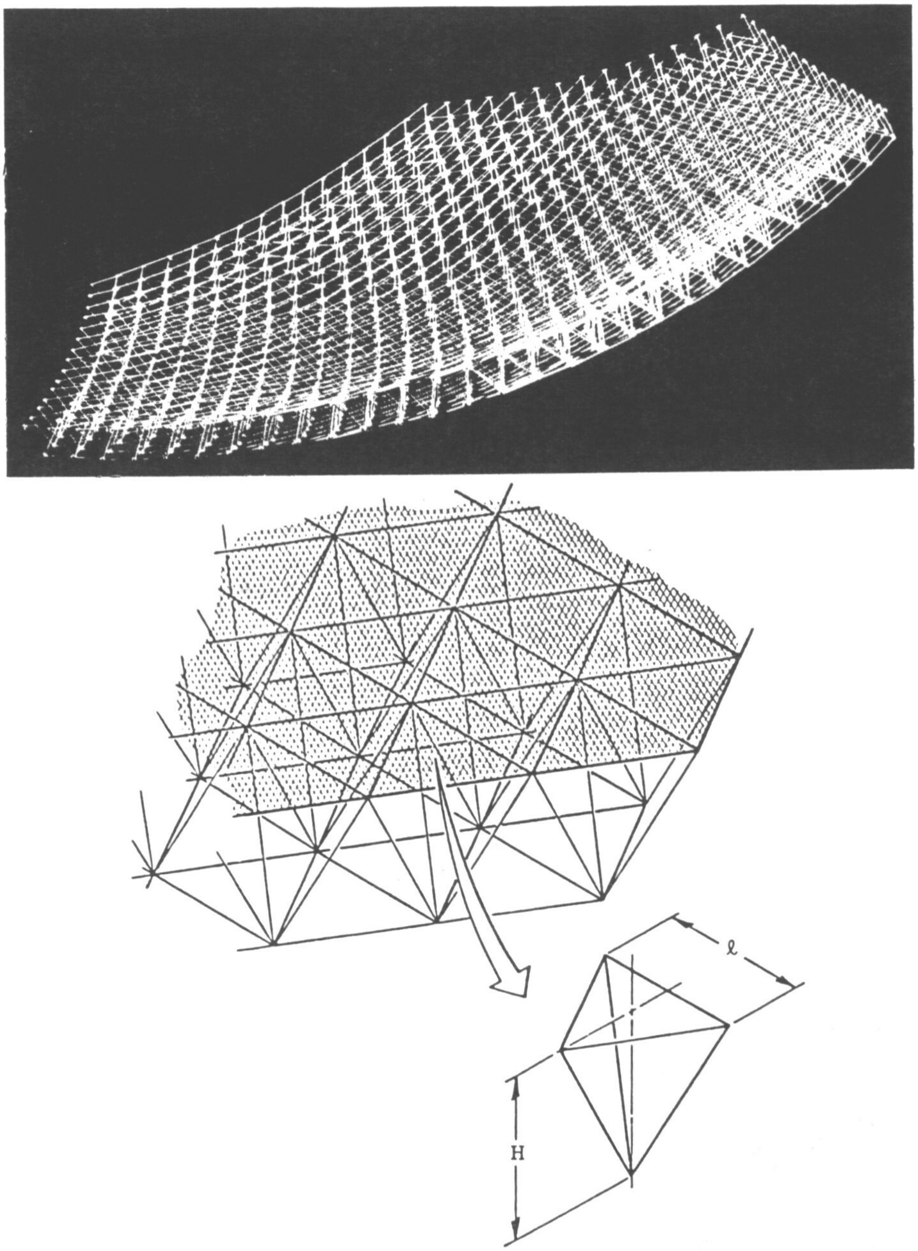

Figure 3

LIMITATIONS DUE TO FABRICATION ERRORS

Our approach is to assemble the structure from elements which are made accurately in detail and are then joined without further adjustment. The effects of the resulting tolerance buildup have been carefully analyzed and reported in ref. 1. Figure 4, taken from that reference, shows the limitations on size due to this tolerance buildup. The achievable diameter-to-wavelength ratio is plotted versus the root-mean-square of the unit length error of the constituent members. We feel that a value of σ_ε of 10^{-5} is achievable with careful tooling without inordinate cost increases. Note that the tetrahedral truss is markedly superior to other configurations and that diameters up to 10,000 wavelengths are achievable.

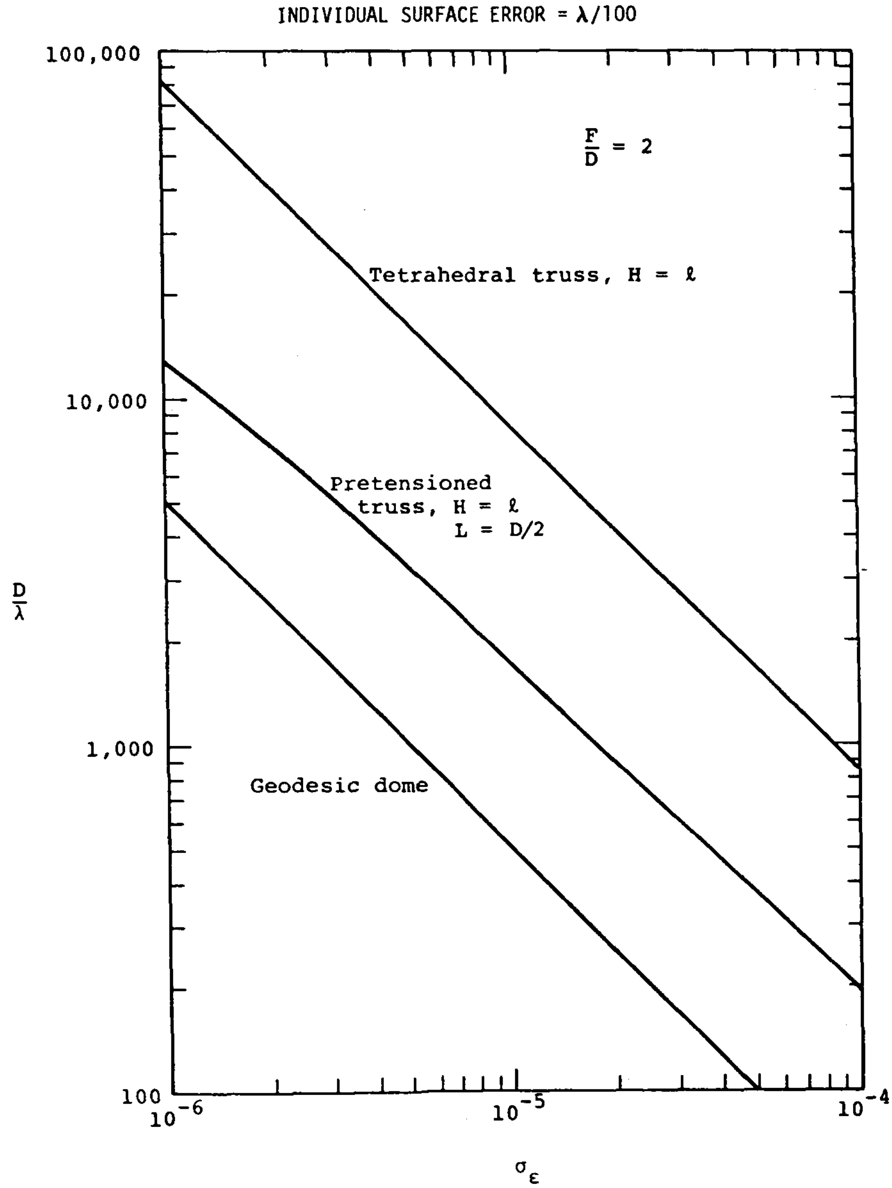

Figure 4

LIMITATIONS DUE TO THERMAL STRAINS

Similarly, the influence of steady-state thermal effects was investigated in ref. 1 for a uniform tetrahedral truss. The summary results shown in figure 5 are plotted against the parameter $\alpha_T T_{max}$. For an α_T of 0.1×10^{-6}/K, a value of this parameter of 3×10^{-5} is appropriate. The results show that the most important static thermal effect is that of self shading. The size potential is around 10,000 wavelengths.

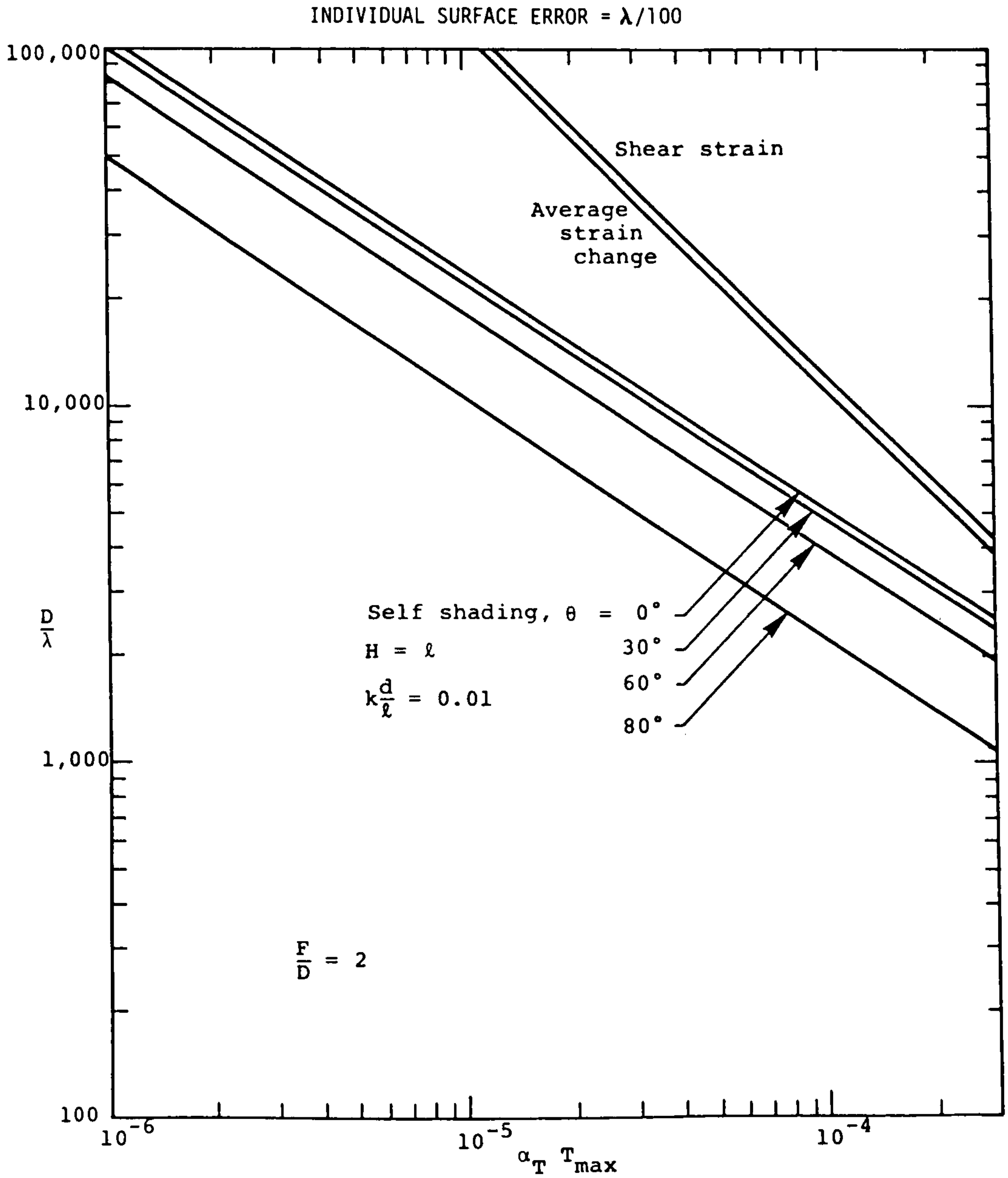

Figure 5

200-METER-DIAMETER DEPLOYABLE ANTENNA

An example antenna configuration which would meet accuracy requirements appropriate for L-band use is shown in figure 6. In this case, the cell size is selected to give an rms error due to facet flattening of 2 mm. The strut diameter is selected large enough so that the deflection of the strut under the mesh tension loads of 2.5 N/m are very small. The natural frequency of the resulting reflector structure is about 1 Hz. Similarly, the resulting structure has a significant capacity for withstanding interorbit acceleration as discussed in ref. 2. The same situation pertains to station keeping loads. Note that the structure is quite complex, being composed of about 1000 facets.

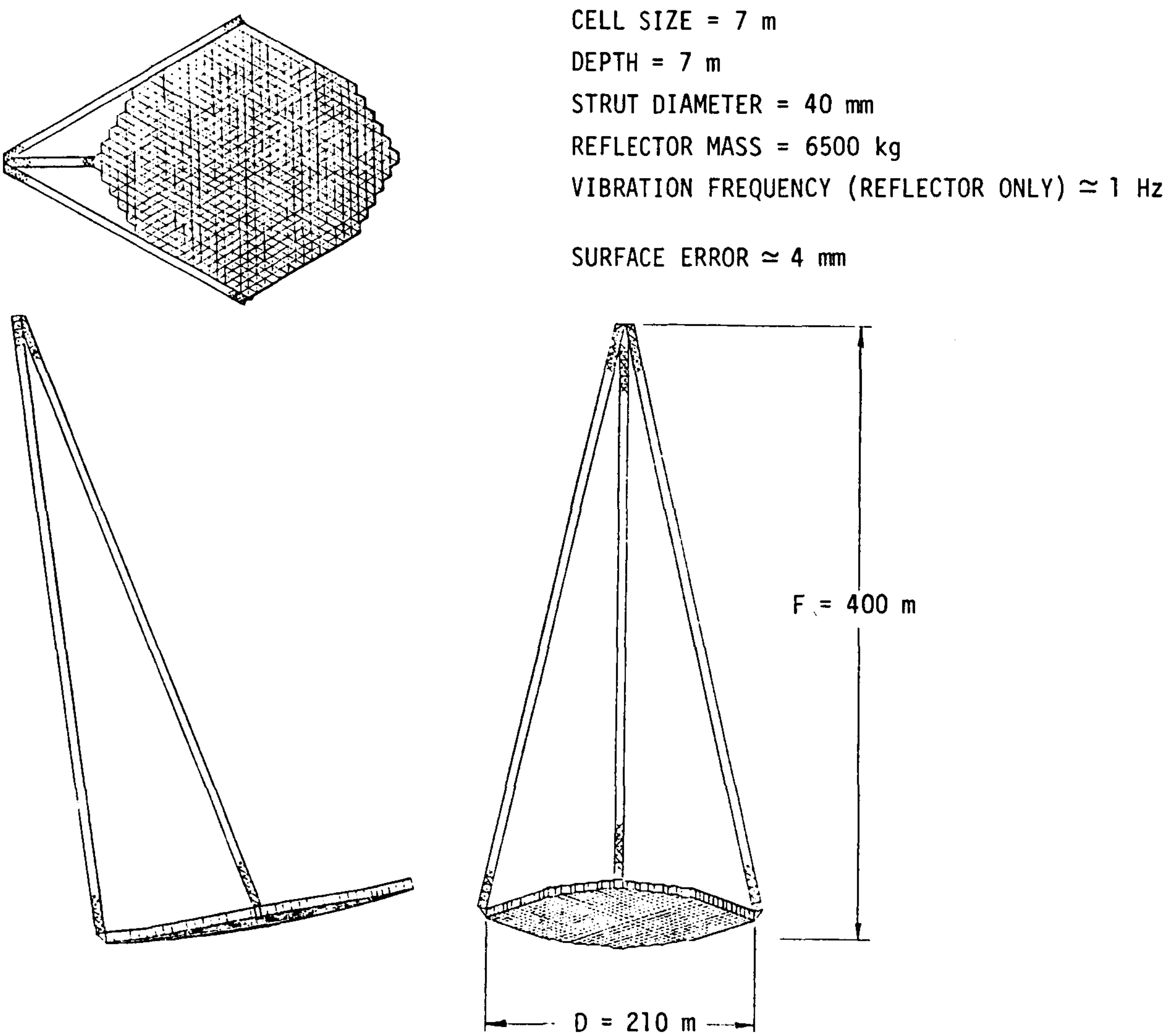

Figure 6

SEQUENTIAL ERECTION

Deploying the entire tetrahedral truss simultaneously is possible but is generally agreed to be difficult to make reliable. In order to achieve reliability, we must obey the principle of sequential erection shown in figure 7. In passing, note that on-orbit assembly is considered by many to be a desirable method for space erection. It follows this principle.

1. *MOST OF THE MATERIAL IS EITHER SECURELY STOWED OR FULLY ERECTED AT ANY TIME DURING THE PERIOD OF ESTABLISHMENT.*
2. *ONLY A SMALL FRACTION OF THE MATERIAL IS IN TRANSITION AT ANY TIME.*
3. *PARTS IN TRANSITION ARE CLOSELY CONTROLLED.*
4. *STRUCTURAL PARTS IN TRANSITION ARE AVAILABLE FOR INSPECTION AND REPAIR.*

Figure 7

PARABOLOIDAL TRUSS PACKAGING

We have invented a new means of packaging and deploying tetrahedral-truss structures. The approach consists of packaging slanted truss planes on top of each other sequentially as shown in figure 8. The truss planes can then be packaged along their length one bay at a time. Models have been constructed to illustrate this process. A fortuitous feature of the paraboloidal shape is that parallel planes intersect with a paraboloid in exactly the same curve. Therefore, the truss planes can be packaged in coincidence even for curved reflectors.

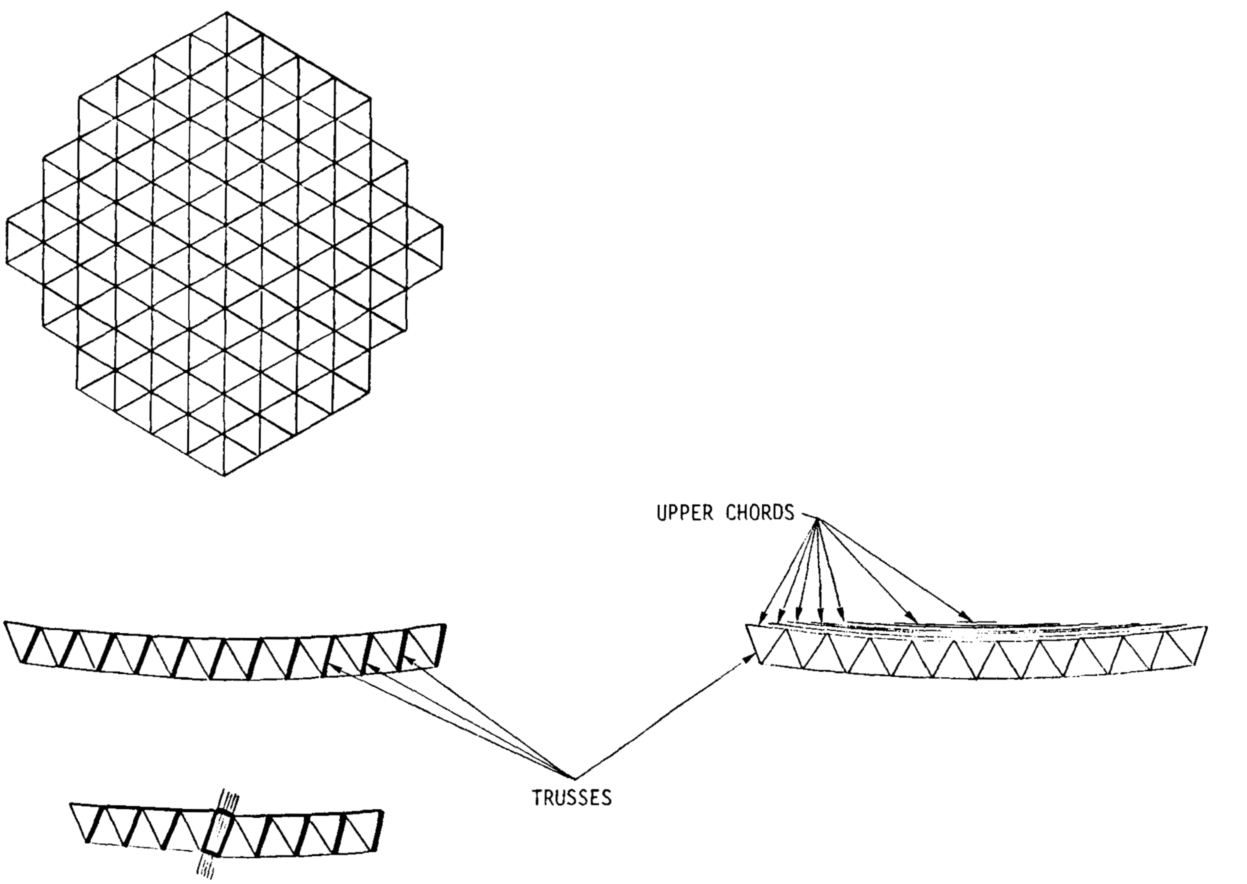

Figure 8

INITIAL DEPLOYMENT

Figures 9 through 11 illustrate the sequence of deployment. At all stages, the partially deployed structure consists of two symmetrical, fully deployed tetrahedral-truss segments which bound fully deployed truss planes. The two canisters with appropriate manipulators control the motion of the truss planes and the essentially rigid bounding tetrahedral-truss segments. In figure 9, the members which have dots in their centers are in the process of being deployed.

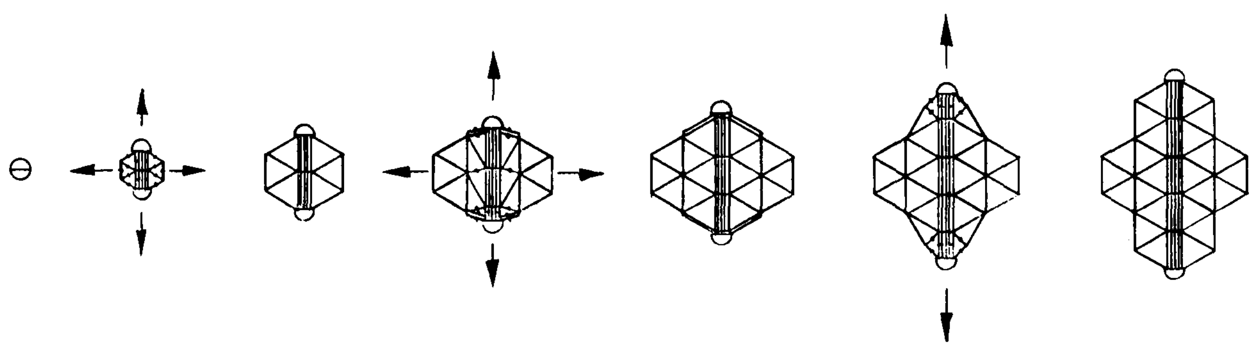

Figure 9

MID-DEPLOYMENT

The truss in mid-deployment is shown in figure 10.

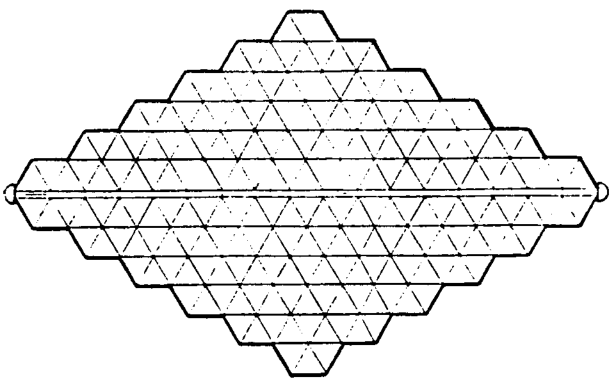

Figure 10

FULLY DEPLOYED

The fully deployed truss has a shape which is governed in part by the character of the deployment (see figure 11).

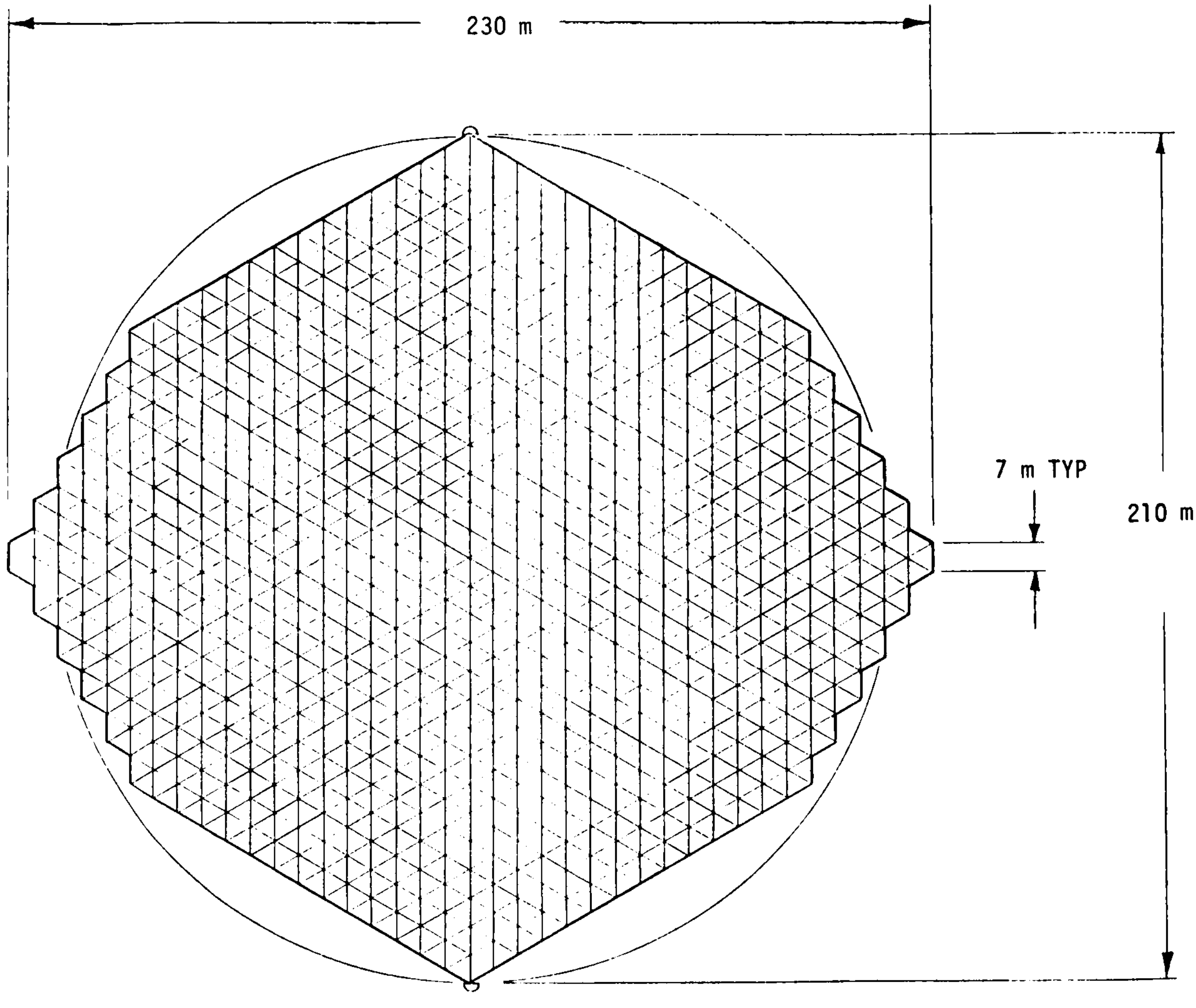

Figure 11

PACKAGED REFLECTOR

The reflector package is shown in figure 12. To this, of course, must be added the packages for the feed support which have not yet been examined.

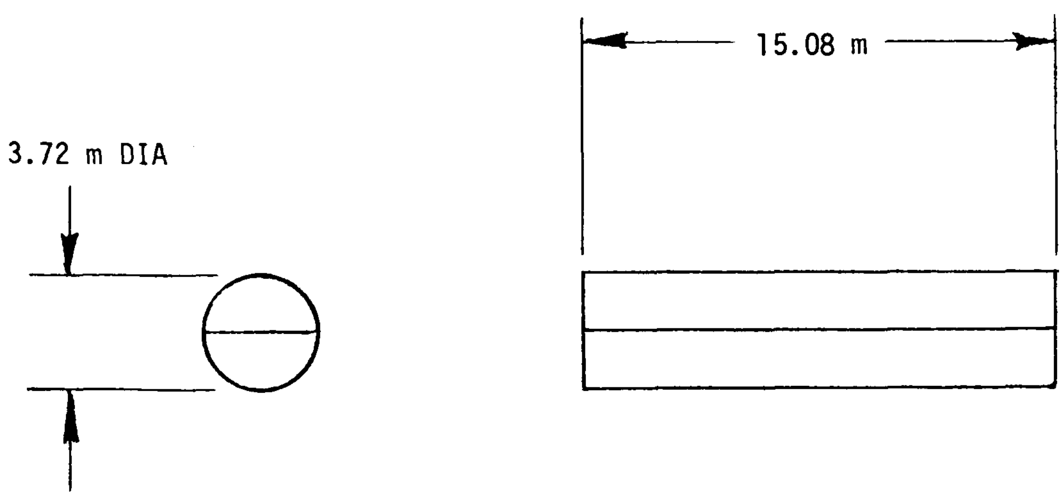

Figure 12

TRUSS STOWED INSIDE CANISTER

The details of the stowage have been examined and the package is shown in figure 13. Note that the surface members are packaged tightly without spaces, thereby maximizing the diameter of the deployed reflector possible in a single Shuttle payload.

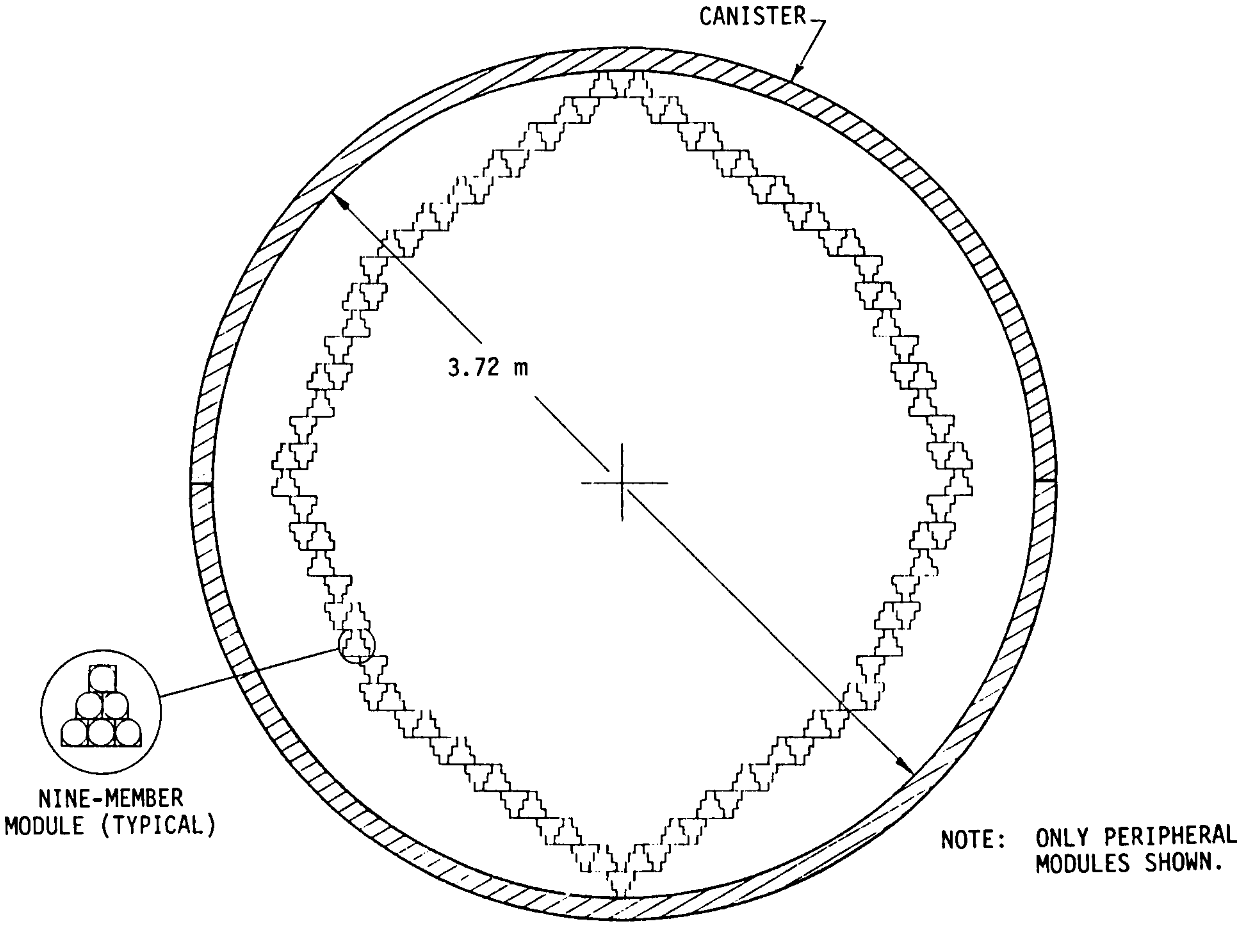

Figure 13

KNEE HINGE

The structure has on the order of 10,000 joints, each of which must operate successfully for a reliable deployment. Joint design is crucial, therefore, to the success of the structure. One joint is shown in figure 14 which makes use of an "almost-over-center" latch, developed and proved as flight hardware on the Seasat Synthetic Aperture Radar antenna structure. This latch provided a lockup of the many knee joints without requiring the close tolerances ordinarily demanded by over-center latches.

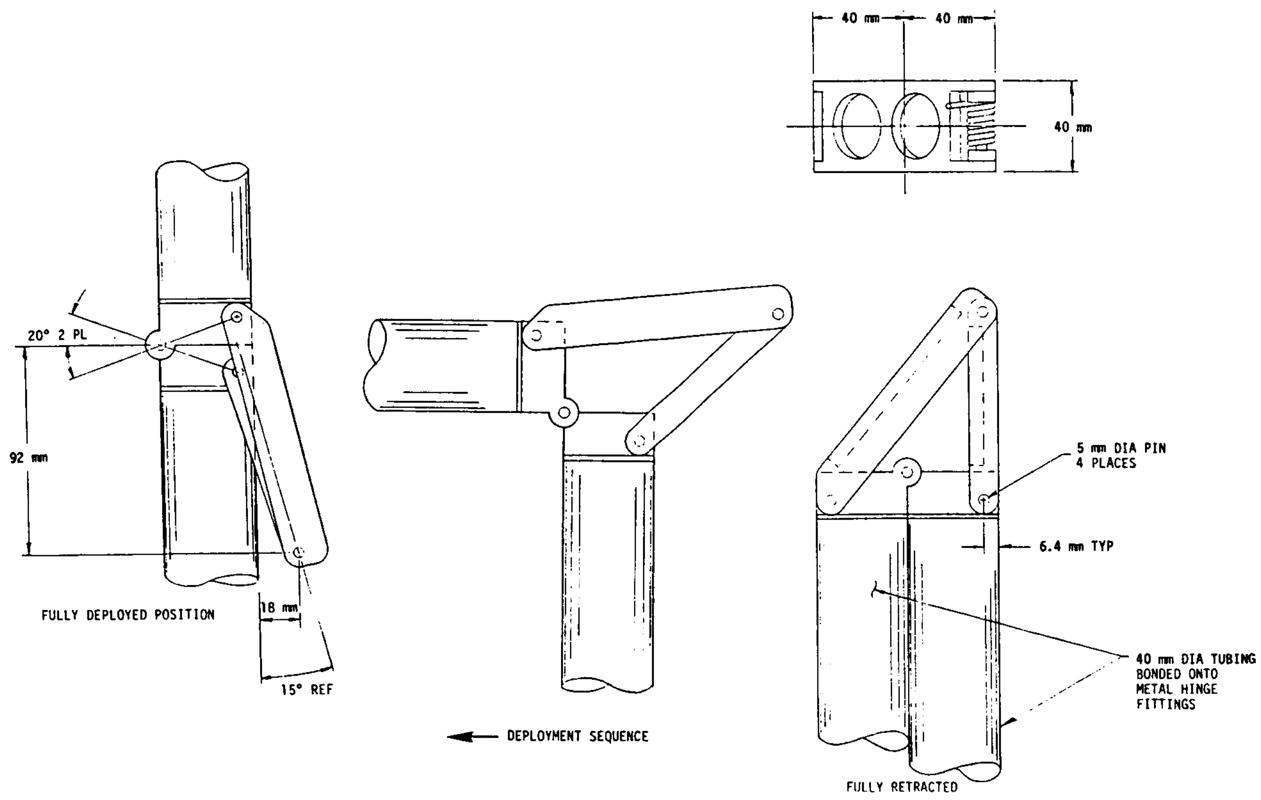

Figure 14

NINE-MEMBER JOINT - TETRAHEDRAL TRUSS

We are in process of designing other joints, the most complex of which is the nine-member joint shown in figure 15 in an obsolete form.

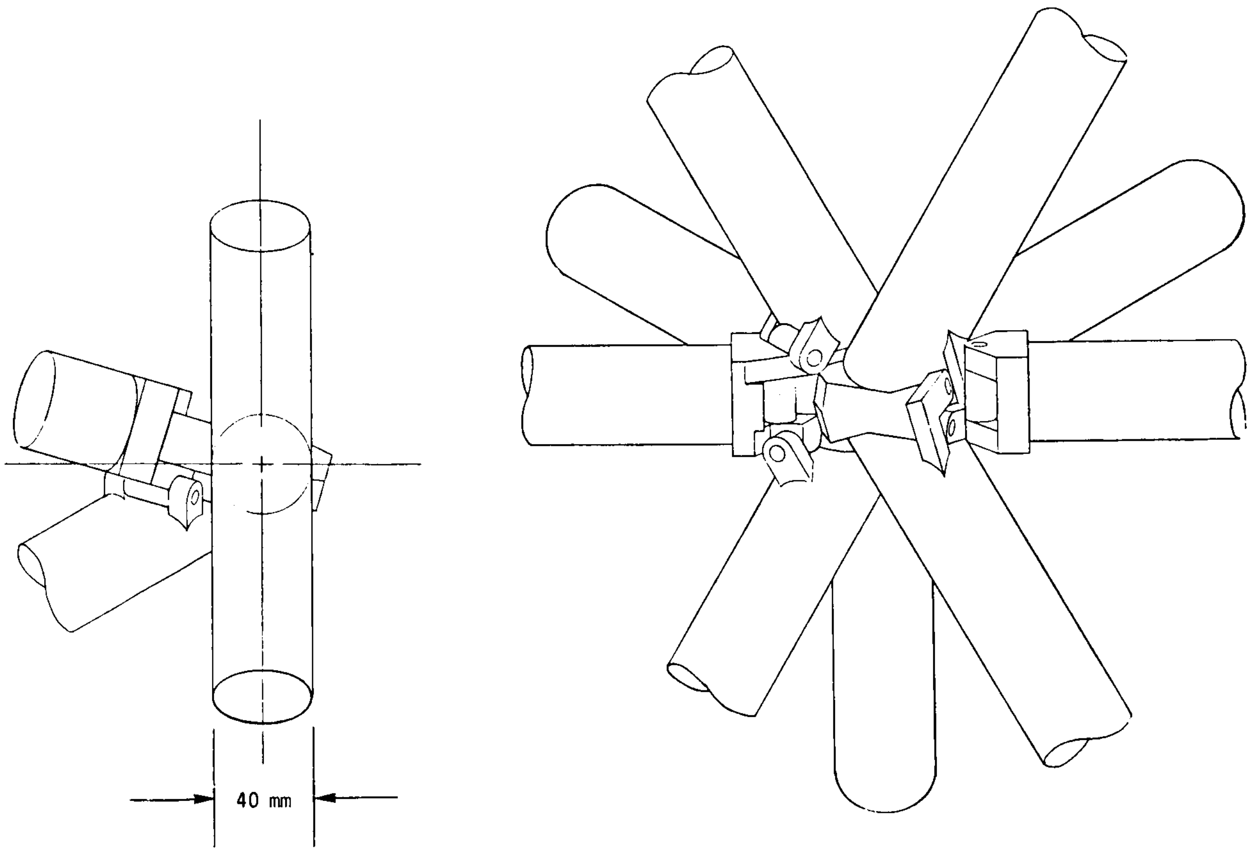

Figure 15

REFERENCES

1. Hedgepeth, John M.: Accuracy Potentials for Large Space Antenna Structures. Space Structures Session of the Society of Allied Weights Engineers 39th Annual Conference (St. Louis, MO), 12-14 May 1980, Paper No. 1375.

2. Hedgepeth, John M.: Influence of Interorbit Acceleration on the Design of Large Space Antennas. LSST/Low Thrust Propulsion Technology Information Exchange Meeting (NASA LeRC), 20-21 May 1980.